JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

EXPLORING THE EFFECT OF NOS/NOT LEARNING AND DISPOSITIONS ON UNDERTAKING BEHAVIOURAL ACTIONS IN THE CASE OF NATURAL HAZARDS

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Abstract. *This research seeks to evaluate students' intended behavioural actions in the event of a natural hazard, specifically hurricane, lightning, earthquake, or tsunami. A test instrument, measuring behavioural actions in the event of a natural hazard, and related NOS/NOT beliefs and dispositions, is utilized to collect data in Estonia, USA and Japan (N=2323). Results suggest that students responded adequately to tsunamis and lightning strikes, but to a lesser extent for hurricanes and earthquakes. Results also suggest a connection between dispositions and behavioural actions, but a lack of connection between generalised. NOS/NOT conceptualisations and behavioural actions. Results imply that students find it difficult to apply their learning to new situations requiring responsible behavioural actions. Implications indicate that NOS/NOT are not well understood, while responsible behavioural actions need to more heavily stressed in teaching about natural hazards involving the promotion of student values and attitudes with respect to Natural Disaster Reduction (NDR).*

Keywords: *behavioural action, Natural Disaster Reduction (NDR), dispositions, Natural Hazards (NH), Nature of Science (NOS), Nature of Technology (NOT).*

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Introduction

Problem of Research

Natural hazards tend to be a science topic taught in schools, but inclusion of a focus on reducing the impact of natural hazards tends to be low. Global climate changes and average temperatures are increasing impacting on the frequency and magnitude of meteorological natural hazards (Emrich & Cutter, 2011; Li et al., 2019). On the other hand, tectonic natural hazards, such as earthquakes, volcanic eruptions and tsunamis tend to form the world's most destructive natural hazards. Unfortunately, the frequencies of casualties and fatalities throughout the world, caused by the impact of natural hazards and the ensuing natural disasters, have also increased (Gallina et al., 2016). Evidence of dangers from natural hazards and disasters is suggested by the severity of hurricanes and other weather-related disasters (Seo, 2014). This connection between natural hazard/disaster frequency and fatalities is likely to increase in the future, as global average temperatures are expected to rise between 0.8° and 4.0° Celsius in the 21st century ("Predictions of future climate", 2017). Further, an increasing population is likely to place more people at risk from-natural hazards. This implies that as natural hazards and disasters risks increase, there is a need to promote responsible actions to take in the event of a natural hazard so as to seek natural disaster reduction (NDR). However, to undertake responsible behavioural action in the case of natural hazards, students require a strong competence background related to a conceptualisation of both NOS and NOT as well an understanding of NDR.

Research Focus

There has been little research on the teaching and learning of undertaking responsible behavioural actions in the event of a natural hazard (Oyao, Holbrook, Rannikmäe, & Pagunsan, 2015; Sims & Baumann, 1983) and the links to positive attitudes towards learning about natural hazards, or the impact of NOS and NOT on science learning.

https://doi.org/10.33225/jbse/19.18.519

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Nature of Science (NOS)

NOS has been suggested as an important learning component as it delineates the limitations of science and the boundaries between what science is and what science is not (McComas, 1998). Previous research indicates that students do not demonstrate an adequate understanding of NOS (Fernandes, Rodrigues, & Ferreira, 2017; McComas, 1998), although, unfortunately, there seems to be no consensus definition of NOS among researchers, philosophers and educators. While researchers disagree on the specific characteristics of NOS (for example, Alters (1997) argues that philosophers of science disagree with the basic tenants of NOS), Alters (1997) argues that there are consensus aspects of NOS. In this context, Lederman (2007) has identified seven consensus aspects of NOS that provide a useful framework, four of which can be measured through a research instrument and hence are applied to provide a more meaningful understanding of natural hazards and associated human behaviours. These relate to:

a) Scientific knowledge is tentative yet durable;
b) The functions of and relationships between scientific theories and laws;
c) There are creative, inferential and imaginative elements involved in the scientific process which should not be overlooked;
d) Empirical observations based on real world evidence

(Smith, Lederman, Bell, McComas, & Clough, 1997; Smith & Scharmann, 1999).

Nature of Technology (NOT)

There is no one definition of NOT and thus any single definition is contested (DiGironimo, 2011; Liou, 2015). There is, however, a consensus view among researchers regarding the bi-directional relationship between science and technology. In other words, researchers agree that technology informs science and science informs technology (Constantinou, Hadjilouca, & Papadouris, 2010). Three potentially important NOT aspects, relevant to undertaking behavioural actions in a natural hazard context, are:

a) *Technology is useful;* The term 'technology' refers to a development which facilitates actions or processes, which serves a useful purpose (DiGironimo, 2011). Thus it is appropriate to seek ways of applying technology to NDR (Raka & Astawa, 2014). For example, because technology can help to reduce risks in the built environment, it is useful to implement natural hazards warning systems, such as those related to hurricane and lightning occurrences (David & Rangaswamy, 2014);
b) *A useful technological process needs to be creative and innovative;* Existing technologies are replaced if they can be improved upon, while novel methods, which are developed through original thinking to support NDR, are both creative and innovative. For example, modern seismographs to detect earthquakes are innovative in that they make use of smart technologies to be more sensitive (Dunnahoe, 2016);
c) *Technology improves;* The more useful technology is, the better. An important consideration for technology, therefore, is that steps are always being taken to make improvements. For example, improvements in the speed and performance in computing power enable the development of more robust predictive models in hazard warning systems and the improvement of physical infrastructure resilience (Pampanin, 2015), reducing risks in the event of a natural hazard.

Dispositions

Dispositions refer to attitudes and values and include interest and a sense of responsibility (OECD, 2006). Dispositions towards responding to a natural hazard can be considered alongside cross-functional skills and knowledge, as components affecting behavioural actions (Oyao, Holbrook, Rannikmäe, & Pagunsan, 2015). Previous research suggests that dispositions encompass a capability (Paton, 2003), or intention (Paton et al., 2008) to act. Further research indicates that dispositions relate to adaptability and flexibility (Anderman, Sinatra & Gray, 2012; P21, 2008), taking responsibility (UNESCO, 2012a) and becoming self-directed learners with a view towards lifelong learning (P21, 2008; UNESCO, 2012a).

https://doi.org/10.33225/jbse/19.18.519

Natural Hazards and Disaster Reduction

The United Nations International Strategy for Disaster Reduction (2009) defines a natural hazard as

> "a natural process, or phenomenon that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (p. 20).

There are two types of natural hazards/disasters: meteorological and tectonic. Natural disaster reduction (NDR) aims to reduce the undesirable impact caused by natural hazards like hurricanes, lightning strikes, earthquakes and tsunamis through impact prevention. Creating awareness of natural hazards is one way to reduce the impacts of natural disasters, as is also the case for tsunamis, which have been covered extensively in the media (Esteban et al., 2018). Other ways to reduce in the impacts of natural disasters can be developing responsible behavioural actions to take when a natural hazard occurs and developing student dispositions.

Enhancing Natural Hazard Reduction through Science Education

Science curricula have shifted from a content, to a relatively more context-focused approach (Eurydice, 2012a, NRC, 2012). It is thus recognised, in the context of natural hazards that an awareness of problems and decisions to be made, as well as appreciating the need for personal and social values, are important and need to relate to the causes and consequences of natural hazards (Cerulli, Holbrook, & Mander, 2016; Oyao, Holbrook, Rannikmäe, & Pagunsan, 2015). Importantly, science curricula encompass the promotion of competences (referred to as: knowledge, skills, attitudes, and values), seeing the teaching of science subjects as more than content (Eurydice, 2012a; NRC, 2012; Prins, Bulte, & Pilot, 2018). In providing students with a context for learning, an understanding of NOS/NOT is valuable in building knowledge leading to undertaking behavioural actions (Cerulli, Holbrook, & Mander, 2016).

While neither NOS and NOT, nor behavioural actions, are explicitly mentioned in the Estonian National Curriculum (Estonian Government, 2011), they can be seen as components of scientific literacy, indicated in the curriculum as the goal for science education. Science curricula in US-East Coast (Maryland) and US-West Coast (California) have transitioned from their respective state standards to embrace Next Generation Science Standards (NGSS) (NRC, 2012). This identifies national standards for students (K-12). An example from NGSS which relates to natural hazards is:

> "Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects" (MS-ESS3-2, p.61).

However, while natural hazards are mentioned, NGSS does not go far enough to encompass teaching/learning contexts related to dealing with natural hazards. In Japan, there is no mention of NOS/NOT (MEXT, 2009).

Behavioural Action

While a behavioural action is how individuals respond to an actual event and, in the context of natural hazards, how individuals actually respond during the occurrence of a natural hazard (Oyao, Holbrook, Rannikmäe, & Pagunsan, 2015), in an artificial situation created to seek likely behavioural action, such as a classroom, it is the intention to act that is being solicited (Paton et al., 2010). Thus in teaching, behavioural intentions, associated with a simulation, are enacted. Nevertheless, behavioural intentions are seen as precursors to adopting actual behaviour (Paton et al., 2008), and are also seen good indicators of actual behaviour (Paton et al., 2010). In fact, prior research on educational approaches in teaching about behavioural action suggests that educators need not begin by teaching behavioural action related to specific natural hazards (Oyao, Holbrook, Rannikmäe, & Pagunsan, 2015), but instead can start by constructing a knowledge base, from the bottom up, to develop informed behavioural responses (Cerulli, Holbrook, & Mander, 2016). Nevertheless, the development of skills to put forward responsible behavioural actions is seen as educationally important (both in a general sense and in a specific sense for dealing with natural hazards).

https://doi.org/10.33225/jbse/19.18.519

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Aims of Research

This research sought to determine students' ability to put forward meaningful behavioural actions in the event of reflecting on a natural hazard situation and whether a knowledge of NOS and NOT, or possessing desirable disposition competences (associated with personal and social values) are useful for undertaking more meaningful responsible behavioural action.

The following research questions were put forward:

1. How far are students able to put forward responsible behavioural actions in the event of a natural hazard such as hurricane, lightning strike, earthquake or tsunami?
2. To what extent do students conceptualise NOS and NOT and how far does the development of disposition competences and an understanding of NOS/NOT facilitate a perceived ability to undertake responsible behavioural actions?

Research Methodology

General Background

This research sought to determine, by means of a test instrument, the manner in which students respond to a situation by going beyond learned knowledge and comprehension and illustrates responsible behavioural actions by applying their learning in situations within which they are not familiar. Putting forward such actions in response to events within a natural hazard environment are also expected to draw upon relevant scientific and technological learning, identified as NOS and NOT. Furthermore, such behavioural actions are expected to be supported by attitudes and beliefs acquired through learning about natural hazards, identified in the questionnaire as dispositions.

Sample

A purposeful sample of students in Estonia, Japan and the United States completed an author-developed instrument, based on teachers' volunteering their students to participate. The involvement of students followed prevailing ethical standards for involving students in research, as per the guidelines in each country.

Teachers were selected using convenience sampling. In Estonia, teachers were identified during a seminar for geography teachers on a volunteer basis. In USA, teachers were found in both Maryland and California on a volunteer basis in Worcester and Los Angeles counties, respectfully. In Japan, students were found in connection with a school affiliated with the University of Chiba.

In United States, the survey was analysed by the education department in Worchester County, Maryland with a view towards determining ethical considerations. One item involving a conflict between science and religion was removed before any student testing took place.

Target grades were 6-12. Specific locations and sample size are indicated in Table 1.

Table 1. Student samples.

Number	Country	City or State*	Sample Size *(N)*	Gender	
				Boys *(N)*	Girls *(N)*
1	Estonia	Nationwide	640	305	335
2	USA	East Coast (Maryland)	449	232	224
3	USA	West Coast (California)	371	174	203
4	Japan	Greater Chiba Area	863	145	718

https://doi.org/10.33225/jbse/19.18.519

Instrument

An earlier devised research instrument (Cerulli, Holbrook, & Mander, 2016) was used for data collection. In Estonia and Japan, where English was not the native language, the original research instrument was translated from English to Estonian/Japanese and subsequently back-translated to English. Any inconsistencies between the original and the back-translated version were identified and adjustments were made accordingly.

The research instrument, consisted of 5 sections and as summarized in Table 2, was administered in section sequence, section 1 being asked first. The sections were ordered in this manner to best reflect a learning progression pyramid (Cerulli, Holbrook, & Mander, 2016).

Table 2. Summary of test sections 1 – 5 in the compiled research instrument.

Section	Description
1	Soliciting student experience with 4 natural hazards – hurricanes, lightning, earthquakes and tsunamis.
2A	Probing student NOS/NOT ideas (see tables 3/5). In version 2A, responses to selected items are open-ended.
2B	Seeking NOS/NOT ideas (but no overlap with 2A). Responses are closed - selected from 2 to 4 options provided.
3	Probing student understanding of the relationship between science and technology from choices presented.
4	Indicating perceived level of danger from 4 natural hazards - hurricanes, lightning, earthquakes and tsunamis.
5	Soliciting behavioural action responses, with respect to the assigned 1 of the 4 natural hazards presented by means of a fictitious map for each hazard.

Behavioural actions were presented based on an earlier devised model (ibid). At the apex of the learning pyramid is behavioural action to be undertaken in a meaningful and responsible manner in the event of a natural hazard. Prior to behavioural action, student learning was presented as re-contextualized through decision making such as a value laden course of action in the event of a natural hazard. At a 2nd level, knowledge was determined from teaching on a need to know basis. At the base of the pyramid is contextualization of the hazard.

Instrument Description and Purpose

A description of each NOS, NOT, or disposition item is given in table 3, together with the aspect or misconception addressed, and the perceived associated with a specific natural hazard included in section 5 to which it is linked. In total, the instrument consists of 13 items.

Table 3. Description of statements; aspect or misconception tested and test type for Section 2 of the test instrument, as well as choices offered in Section 2B.

Item no.	Statement	Aspect, or misconception tested	Section 2B Explanations				Test Type*
			A	B	C	D	
1	Meteorologists can determine precisely how many hurricanes will strike in a given area every year by utilizing modern technology and science.	NOS - Scientific knowledge is tentative yet durable	Yes, it's possible.	Weather cannot be predicted with 100% accuracy.	No, Weather cannot be predicted.		H, L, E
2	Scientific understanding of natural hazards is evolving.	NOS - Scientific knowledge is tentative yet durable.	Yes, there will be further investigations.	Scientific understanding evolves as technology improves.	Research opportunities are improving.	Enough is known already.	H, E, T

https://doi.org/10.33225/jbse/19.18.519

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Item no.	Statement	Aspect, or misconception tested	Section 2B Explanations				Test Type*
			A	B	C	D	
3	Volcanoes erupt because the volcano god Vulcan is angry with humans.	NOS - Pseudo-Scientific beliefs.	I believe the 'gods' are doing it.	Nobody has proven otherwise.	I don't believe in the supernatural.	The occurrence of natural hazards is scientific.	H, L, T
4	Designing an effective hurricane [either individual/family or societal] evacuation plan requires a lot of creativity.	NOS - There are creative, inferential &imaginative elements involved in the scientific process.	Yes, creativity can save people's lives.	It depends on the situation.	You should be practical and logical, not creative.		H, L, T
5	The theory of plate tectonics is gaining acceptance in the scientific community and therefore it will soon progress from a theory to a law.	NOS - The functions of and relationships between scientific theories and laws.	A theory can become a law.	It doesn't happen, however, it's possible.	I'm not sure how they feel about it in the scientific community.	A theory can never become a law.	L, E, T
6	Technology and human action induce earthquakes.	NOT - Technological and social systems interact strongly.	Yes, it's possible, there are machines that generate vibrations, for example.	It could be possible in the future.	Man cannot induce natural hazards.		H, L
7	Because humans can control nature by using technology, it is possible to build a home in any location.	NOT - All technological systems can fail.	Yes, if there are sufficient resources.	No precise predictions are possible.	Nature cannot be controlled.	You can't build everywhere.	H, L, T
8	By using technology, it is always possible to predict the exact path of a hurricane.	NOT - The human presence in technology.	Yes, technology has advanced enough.	Somewhat, predictions can be quite accurate.	The hurricane could change direction.	No, nature cannot be predicted.	H, L, E
9	Doppler radar is an example of technology, which is used to support science.	NOT - Technology draws on science and contributes to it.	Not Asked.	Not Asked.	Not Asked.	Not Asked.	L, E, T
10	When responding to natural hazards, the safety of others is as important as my individual safety.	Dispositions.	It's better to save more people than to be saved yourself.	First help yourself, then help others.	You shouldn't put yourself at risk by saving others.	Every man for himself.	H, E, T
11	When determining risk associated with a natural hazard, personal safety is more important than financial gain.	Dispositions.	Financial gain won't matter when I'm unsafe.	Both are important.	Finance is more important.		L, E, T
12	It's important to know how to respond to a tsunami even if I don't live near a large body of water.	Dispositions.	Tsunamis' extend beyond the water's edge.	It would be important while traveling.	Why should I need to know that if it's unlikely I will need it?		L, T
13	Learning about earthquakes is only important if you live near a plate boundary or fault.	Dispositions.	It's only important if you live in an earthquake prone region.	It's important in case you're traveling.	Earthquakes occur outside plate boundaries.		H, L, E

**H=Hurricane; L=Lightning; E=Earthquake; T=Tsunami.*

https://doi.org/10.33225/jbse/19.18.519

Section 1 determined student experiences with hurricanes, lightning, earthquakes and tsunamis.

Section 2 probed student knowledge of NOS, NOT and dispositions. Any one student was asked to respond to 4-7 items in section 2A, plus 3 to 5 different items in section 2B which were seen as specifically paired with a natural hazard response scenario in section 5. For example, item 1 from section 2B, "Meteorologists can determine precisely how many hurricanes will strike in a given area every year by utilizing modern technology and science" was considered most relevant to the hurricane scenario. The distribution of NOS, NOT and disposition items from section 2 were as indicated in table 4.

Table 4. Distribution of items (1-13) from either sections 2A or 2B indicated by hazard-related type.

Section 2 Items	Items in Hurricane test version	Items in Lightning test version	Items in Earthquake test version	Items in Tsunami test version
Section 2A – response only required				
Items related to NOS	3	1, 4, 5	1, 2	2, 3, 4, 5
Items related to NOT	6, 7	8	9	9
Items related to dispositions	10, 12, 13	11	11	-
Section 2B - explanation choice required in addition				
Items related to NOS	1, 2, 4	3	5	-
Items related to NOT	8	6, 7	6, 8	-
Items related to dispositions	-	12, 13	10	10, 11, 12

Section 3 was included in each version of the instrument to determine whether a bi-directional relationship between science and technology is recognized by students, i.e. a bi-directional relationship implies that technology improves science and science improves technology (Constantinou, Hadjilouca, & Papadouris, 2010).

Section 4 examined student perceptions of natural hazard severity, plus revealing their risk perceptions about each hazard type.

Section 5 tested students' behavioural action capabilities in 1 of 4 versions to allow for coverage of 4 different natural hazards, without the testing time being too time-consuming. The four versions were as indicated in table 5. Each version gave an appropriate natural hazard scenario and a corresponding map depicting a fictitious island nation prone to the specified natural hazard. The test items sought to relate to four contextualized levels (Cerulli, Holbrook, and Mander, 2016). The test instrument was sub-divided so that each student responded to 1 of 4 natural hazard versions. The number of students tested by each version in each of the countries/regions was as indicated in table 5.

Table 5. Test versions undertaken by students broken down by grade level and country.

	Test Versions			
Country/ Region	Version 1 (section 5 about Hurricanes)	Version 2 (section 5 about Lightning)	Version 3 (section 5 about Earthquakes)	Version 4 (section 5 about Tsunamis)
Estonia	*N*=178	*N*=167	*N*=167	*N*=128
US-East Coast	*N*=105	*N*=121	*N*=122	*N*=108
US-West Coast	*N*=65	*N*=127	*N*=99	*N*=87
Chiba, Japan*	*N*=142	*N*=108	*N*=76	*N*=140

**In the Japanese student sample, the additional students indicated in table 1 received a test instrument lacking section 5 (N=397).*

https://doi.org/10.33225/jbse/19.18.519

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Instrument Development

The instrument was initially piloted with 135 students in Estonia and 55 students in United States and subsequently modified. Based on the outcomes, modifications were made (Cerulli, Holbrook, & Mander, 2016).

Data Collection

The instrument was administered to students in grades 6-12. Each student received, arbitrarily, 1 of 4 versions of the questionnaire, with a separate colour map of a fictitious island (nation).

In Japan, the first author (as principle researcher) was not present during data collection because eight classes were simultaneously administered, which was necessary due to time constraints. Only 10 minutes were provided for students to complete the test, and thus the instrument was shortened. The 4 versions of the instrument in section 5 were divided into two instruments - lightning and earthquake were primarily assigned to basic/middle school students while hurricane and tsunami were largely assigned to advanced/high school students (based on perceived level of difficulty). Each of the four scenario questionnaires had a reduced amount of items i.e. half the items were removed, for sections 2A/2B; Sections 3 and 4 were omitted. The instrument without section 1, reduced items for sections 2A/2B but included section 5 was administered to 466 students. A further 397 students were assigned an instrument version containing items from section 1, reduced items from section 2A/2B and items from section 4. Data collection and coding were as indicated in table 6.

Table 6. Data collection and coding for sections 1 through 5.

Section	Data Collection / Coding
1	Students were asked to indicate experience with (a) hurricanes; (b) lightning; (c) earthquakes; (d) tsunami.
2A	Responses to items in 2A required no student explanations but to indicate whether they agree or disagreed with each statement. Agree/disagree statements were recorded as either 1(acceptable response) or 0 (unacceptable response) depending on the question.
2B	Responses to items in 2B required students to select the appropriate explanation from two-four options (depending on the item). Responses were coded as either 1 (acceptable explanation) or 0 (unsuitable explanation).
3	Open ended student responses were coded into one of four categories. Responses were categorized into 1 of 4 groups. Group 1- There is some connection between science and technology; Group 2- Technology seen as applied science; Group 3 - Bi-directional relationship between science and technology; Group 4 - other responses. Responses from group 3 were coded as an acceptable response while responses from groups 1, 2 and 4 were coded as unacceptable responses.
4	Students were asked to place a 4 next to the natural hazard that was considered most dangerous; 3 next to the natural hazard considered second most dangerous; 2 third most dangerous and 1 for least dangerous.
5	Behavioural action and all sub-components in section 5 were coded as either: (1) responsible; or (0) irresponsible. Student responses were deemed responsible if the student responded in a way that reduces risks and saves lives, and was in alignment with hazard safety knowledge. Other responses were deemed irresponsible.

Data Analysis

Valid percentages of positive/correct responses per section were determined per country/region. Where appropriate, data analysis was undertaken by type of natural hazard. NOS/NOT/Dispositions were matched separately with positive and negative behavioural actions by undertaking frequency counts (and Spearman's correlations).

Validity and Reliability

Construct and content validity was checked both by consulting expert opinion plus from piloting and analysing the feedback and further elucidated as in Cerulli, Holbrook and Mander (2016).

https://doi.org/10.33225/jbse/19.18.519

Research Results

Hazards Experienced

Students were asked to indicate their personal experience of natural hazards i.e. hurricanes, lightning strikes, earthquakes or tsunamis. Results are illustrated in Table 7.

Table 7. Student experiences (%) with respect to selected natural hazards.

Region/ Country	*N*	Natural Hazard Experienced							
		Hurricane		Lightning		Earthquake		Tsunami	
		Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)
Estonia	640	4.7	95.3	82.0	18.0	5.5	94.5	0.5	99.5
US-East Coast	448	88.8	11.2	89.7	10.3	56.6	43.4	0.4	99.6
US-West Coast	358	6.5	93.5	65.6	34.4	94.3	5.7	0.6	99.4
Japan	863	98.0	2.0	91.5	8.5	99.2	0.8	1.7	98.3

Percentage of no responses is <1%.

Understanding of Nature of Science, Nature of Technology and the Role of Student Dispositions

Students were asked to respond to the set of Likert-scale items (N=13) covering NOS, NOT, student dispositions through a context of natural hazards. Results were as illustrated in table 8.

Table 8. Percentage of positive student responses in the 4 country/regions for each item in section 2A.

Country/ Region	*N*	Section 2A - Positive student responses (by item)												
		1	2	3	4	5	6	7	8	9	10	11	12	13
		NOS (%)	NOS (%)	NOS (%)	NOS (%)	NOS (%)	NOT (%)	NOT (%)	NOT (%)	NOT (%)	Disp (%)	Disp (%)	Disp (%)	Disp (%)
Estonia	640	22.2	33.3	29.7	26.2	17.9	31.8	21.5	20.6	31.8	30.4	75.9	39.1	10.8
US-East Coast	448	41.0	87.2	88.6	28.7	41.4	45.7	17.4	39.9	74.3	80.2	81.8	85.2	16.8
US-West Coast	358	19.1	80.3	85.3	52.0	14.3	29.8	48.6	24.8	60.7	77.3	74.3	79.5	24.0
Japan	863	11.5	82.2	81.5	62.7	29.0	10.0	78.1	41.7	65.8	73.1	83.9	93.9	81.2

Disp=disposition items.

Positive Student Explanations in Estonia, US-East Coast, US-West Coast and Japan for Items in Section 2B

Students were subsequently asked to provide an explanation for their responses in Section 2A for 3-5 items, depending on instrument version. A choice of two to four explanations was provided as a context for students. The results were as illustrated in table 9.

https://doi.org/10.33225/jbse/19.18.519

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 9. Percentages responses of positive student explanations to section 2B items.

Country/ Region	N	Section 2B - Positive Explanations for student responses (by item)												
		1	2	3	4	5	6	7	8	9	10	11	12	13
		NOS (%)	NOS (%)	NOS (%)	NOS (%)	NOS (%)	NOT (%)	NOT (%)	NOT (%)	NOT (%)	Disp (%)	Disp (%)	Disp (%)	Disp (%)
Estonia	640	82.1	72.4	82.3	61.1	56.8	63.8	69.8	69.5	N/A	91.4	77.1	85.7	52.6
US-East Coast	448	83.5	88.5	89.2	60.2	20.5	47.8	25.0	59.8	N/A	88.5	87.0	94.2	20.5
US-West Coast	358	55.3	69.2	73.0	71.2	49.2	77.2	58.4	59.3	N/A	67.9	67.5	89.5	32.3
Japan	863	98.6	91.4	59.8	26.1	45.2	64.0	27.2	23.2	N/A	87.2	97.0	81.2	68.6

D=disposition items; N/A – accidentally not asked in 2B.

The Inter-relationship between Science and Technology

Student understanding of the inter-relationship between science and technology was tested with a view towards evaluating a potential connection with responsible behavioural action. Student percentage responses were as illustrate in table 10.

Table 10. Student responses on the relationship between science and technology.

Region/Country	N	Student Response Categories			
		1 – There is some connection (%)	2 – Technology seen as applied science (%)	3 – Bi-Directional relationship (%)	4 – Other responses (%)
Estonia	640	28.4	28.0	22.2	21.4
US-East Coast	448	58.5	12.1	22.6	7.8
US-West Coast	358	52.8	12.0	13.2	22.0
Japan	863	10.2	19.8	59.2	9.6

Student Perceived Danger of Natural Hazards

Students' perceptions regarding which natural hazards were perceived to pose the greatest or least danger were as indicated in table 11.

Table 11. Relative percentage rankings of the perceived level of danger from hurricanes, lightning, earthquakes and tsunamis.

Country/ Region	N	Hazard	Student responses			
			Least Dangerous (%)	Second Least Dangerous (%)	Second Most Dangerous (%)	Most Dangerous (%)
Estonia	640	Hurricane	7.4	39.8	31.4	21.4
		Lightning	81.9	8.4	4.9	4.9
		Earthquake	7.2	37.2	36.5	19.1
		Tsunami	3.5	14.2	27.4	54.9

https://doi.org/10.33225/jbse/19.18.519

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Country/ Region	N	Hazard	Student responses			
			Least Dangerous (%)	Second Least Dangerous (%)	Second Most Dangerous (%)	Most Dangerous (%)
East Coast, USA	449	Hurricane	10.9	32.5	36.7	19.9
		Lightning	67.4	18.8	6.7	7.0
		Earthquake	16.5	33.0	28.5	22.0
		Tsunami	5.2	14.5	27.4	52.9
West Coast, USA	371	Hurricane	14.4	32.3	34.3	19.0
		Lightning	52.1	7.4	8.9	31.6
		Earthquake	16.6	36.3	29.8	17.3
		Tsunami	17.3	23.9	26.9	31.9
Chiba, Japan	863	Hurricane	14.4	36.9	32.8	16.0
		Lightning	47.3	10.4	7.2	35.1
		Earthquake	14.0	31.4	36.4	18.1
		Tsunami	24.3	20.8	23.5	31.4

Behavioural Action Scenarios Related to Natural Hazards

Students responded to questions in section 5 based on a specific natural hazard. Responses to the questions in section 5 were broken down by country/region.

Table 12. Students deemed to indicate responsible behavioural actions in the case of hurricane, lightning, earthquake and tsunami, by country/region.

Country/Region	N	Percentage student responses to each Natural Hazard			
		Hurricane (%)	Lightning (%)	Earthquake (%)	Tsunami (%)
Estonia	642	35.4	69.9	38.7	84.7
US-East Coast	445	52.3	50.0	25.4	63.4
US-West Coast	360	49.1	36.3	57.0	60.0
Japan	479	45.8	59.6	82.7	74.4
Total	1926	46.8	55.3	46.0	71.4

Behavioural Action in the Event of a Natural Hazard and NOS, NOT and Dispositions

The inter-relationship between responses to sections 2A/B and 5 are viewed as particularly important, because they most directly answer the goals and research questions of this study. Table 13 illustrates the relation between categories of explanatory responses for NOS, NOT, dispositions and the 4 natural hazards included in the instrument (hurricane, lightning, earthquake and tsunamis).

In table 13, responses per student for NOS, NOT and disposition items were compared with behavioural action responses in the case of each natural hazard. Data sets from all samples were combined using clustering. Responses from similar questions from sections 2A and 2B along with behavioural action were analysed in clusters based on patterns of 1 (correct response) and 0 (incorrect response). The higher frequency response pattern across students were identified as shown in table 13, the use of 'I' refers to item, 'A' indicates item as per section 2A, 'B' item as per section 2B, 'BA' is the overall behavioural action response and TOTAL indicates the number of students providing the specific response pattern.

https://doi.org/10.33225/jbse/19.18.519

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 13. The connections between NOS, NOT, dispositions and behavioural action put forward with respect to a hurricane, lightning, earthquake and tsunami.

Nature of Science - Hurricane						Nature of Technology - Hurricane					Dispositions - Hurricane				
I-3A	**I-1B**	I-2B	**I-4B**	BA	**TOTAL**	I-6A	I-7A	I-8B	BA	**TOTAL**	**I-10A**	**I-12A**	**I-13A**	BA	**TOTAL**
0	1	1	1	1	42	0	0	0	1	57	0	0	0	1	68
1	1	1	1	1	23	1	0	0	1	22	1	1	0	1	20
0	1	1	1	0	74	0	1	0	1	19	0	0	0	0	127
1	1	1	1	0	31	0	0	0	0	110	1	1	0	0	31
1	1	1	0	0	18	1	0	0	0	46	0	0	1	0	16
0	1	1	0	0	17	0	1	0	0	33	-	-	-	-	-
0	0	0	0	0	15	-	-	-	-	-	-	-	-	-	-

Nature of Science – Lightning						Nature of Technology - Lightning					Dispositions - Lightning				
I-1A	**I-3B**	**I-4A**	**I-5A**	BA	**TOTAL**	I-6A	I-7A	I-8A	BA	**TOTAL**	**I-11A**	**I-12B**	**I-13B**	BA	**TOTAL**
0	1	1	0	1	65	0	0	0	1	69	1	1	1	1	114
1	1	1	0	1	38	1	0	0	1	55	0	1	1	1	64
0	1	1	1	1	22	1	0	1	1	21	1	1	1	0	78
0	0	1	0	1	21	0	0	1	1	16	0	1	1	0	77
0	1	1	0	0	66	0	1	0	1	15	0	0	0	0	19
0	0	1	0	0	32	0	0	0	0	84	-	-	-	-	-
0	1	1	1	0	28	1	0	0	0	33	-	-	-	-	-
1	1	1	0	0	25	0	1	0	0	27	-	-	-	-	-
0	0	0	0	0	17	0	0	1	0	24	-	-	-	-	-

Nature of Science - Earthquake						Nature of Technology - Earthquake					Dispositions - Earthquake				
-	**I-1A**	I-2A	**I-5B**	BA	**TOTAL**	I-9A	I-6B	I-8B	BA	**Total**	-	**I-10B**	**I-11A**	BA	**TOTAL**
-	0	1	0	1	53	0	1	0	1	64	-	1	1	1	62
-	0	0	0	1	44	0	0	0	1	29	-	0	1	1	55
-	1	1	1	1	21	1	1	0	1	18	-	1	1	0	132
-	0	0	0	0	104	0	0	0	0	102	-	0	1	0	70
-	0	1	0	0	71	0	1	0	0	87	-	1	0	0	24
-	1	0	0	0	32	1	1	0	0	19	-	0	0	0	23
	1	1	0	0	26	1	0	0	0	19	-	-	-	-	-

Nature of Science – Tsunami						Nature of Technology - Tsunami					Dispositions - Tsunami				
I-2A	**I-3A**	**I-4A**	**I-5A**	BA	**TOTAL**	-	-	I-9A	BA	**TOTAL**	**I-10B**	**I-11B**	**I-12B**	BA	**TOTAL**
0	0	0	1	1	59		-	0	1	159	1	0	1	1	133
1	1	0	1	1	42	-	-	1	1	33	0	1	0	1	75
0	0	1	1	1	22	-	-	0	0	95	1	1	1	1	26
1	1	0	0	1	21	-	-	1	0	36	0	0	1	1	17
1	1	0	1	0	46	-	-	-	-	-	0	1	1	1	15
0	0	0	1	0	22	-	-	-	-	-	1	0	1	0	75
1	1	0	0	0	16	-	-	-	-	-	0	1	0	0	36
-	-	-	-	-	-	-	-	-	-	-	1	1	1	0	27

Response less than 15 were removed to allow for simplicity.

https://doi.org/10.33225/jbse/19.18.519

Discussion

Students tended to indicate they had experienced at least one form of natural hazard, mostly of a meteorological kind. Thus, Estonian students indicated they had experienced lightning in over 80% of cases, while for students from the US-East Coast this was the case for both hurricanes and lightning. Students from the US-West Coast indicated that hurricane and earthquakes were experienced in more than 80% of cases. However, in Japan, hurricanes, lightning and earthquakes were all experienced more than 80% of the time. Tsunamis were rarely experienced by any student.

A pattern seemed to emerge related to perceived danger of natural hazards, suggesting similar responses between Estonia/US-East Coast (countries primarily experiencing meteorological dangers) and US-West Coast/Japan (primarily experiencing tectonic dangers). Nevertheless, perceptions of the danger of natural hazards varied by country. While Japanese students seemed to perceive lightning as either the least and most dangerous, students from other countries felt tsunamis were the most dangerous and lightning the least. Noting lightning, in general, was the most experienced and tsunamis the least experienced natural hazard (table 7), this tended to suggest that natural hazards which were experienced the least, were feared the most, and vice versa, where natural hazards were experienced the most, they were feared the least.

Students, in general, seemed to find it difficult to respond to, and give, responsible behavioural actions; this applied for all natural hazards and for students across all countries/regions. In general, the percentage of acceptable behavioural actions were low. On the US-West Coast, approximately one third of the student sample responded responsibly to lightning strikes, less than the combined average total. This suggested a possible connection between experience with lightning and behavioural action. Students from Estonia showed the highest percentage responsible behavioural action with respect to tsunamis. This contrasts with percentage responses, for lightning and hurricanes, in the student sample from the US-West Coast, which gave the highest proportion of responsible behavioural action responses.

Students seemed to have difficulties to reach the higher levels of learning associated with the proposed learning progression model. These results were in line with findings from a study by Grothmann and Reusswig (2006) which indicated that during a flooding event in Cologne, Germany, responsible behavioural actions were deemed inadequate. The lack of skill to undertake responsible behavioural actions might result from a lack of a theoretical underpinnings within the curriculum (OECD, 2006). While preparing for, and responding to, natural hazards were included in NGSS, mention of responses to natural hazards were lacking in any comprehensive structure. The NGSS did not draw specific attention to the need to put forward responsible behavioural actions, in which students were expected to transfer learning to a new situation and thereby showing an ability to play a role in NDR. In fact, the NGSS (NRC, 2012), only included random mentions of responses to natural hazards. For example, the closest fit with respect to natural hazards in the curricula was related to meteorological events:

> "Ask questions to obtain information about the purpose of weather forecasting to prepare for, and respond to, severe weather" (K-ESS3-2 p.7).

However, actions to take in the event of a natural hazard were included in the Japanese curricula (MEXT, 2009), For example:

> "Shift from 'knowledge-based' to 'the nurturing of the ability to behave independently [shutaiteki ni koudou suru taido]' so as to make decisions flexibly in facing a disaster" (Kitagawa, 2015, p. 14).

As responding to natural hazards is included in the curriculum in Japan, it is expected that behavioural action would also have the highest percentage of responsible behavioural action for natural hazards. However, apart from earthquakes (table 12), this is not the case.

While considerations of natural hazards were included in the Japanese curricula this did not seem to be the case for Estonia and the US-East and US-West coasts. As curriculum standards did not specifically include responsible behavioural actions to take in the event of a natural hazard (NRC 2012; Estonian Government, 2011), not surprisingly, the results obtained were poor. But even though behavioural action in the case of a natural hazard was mentioned explicitly in the Japanese curriculum (MEXT, 2009), Japanese responsible behavioural action results were only significantly higher with respect to responses to earthquakes, where the sample of Japanese students indicated they had most commonly experienced earthquakes (99.2%), when compared with students in the US and Estonia.

https://doi.org/10.33225/jbse/19.18.519

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

As tsunami responses showed the highest percentage of responsible behavioural actions (table 12), as well as the highest level of fear (table 11), yet the lowest level of experience (table 7), this suggested that other factors besides learning in school were impacting on the decision making e.g. media influence on behavioural action beyond actual experiences. Other factors seemed likely in the case of other natural hazards. While only around 60% students, over all regions, were able to identify areas on the fictitious island nation map that were considered safer in the event of a lightning strike, suggesting that lightning safety knowledge was understood by the majority of students, there were still many students who did not understand risks associated with lightning strikes. The results suggested that lightning safety knowledge was generally being acquired outside of the classroom through, for example, the media or non-profit, state awareness, programmes. Nevertheless, the majority of students (who responded to the test instrument with respect to lightning) were aware of the risks associated with lightning strikes, as most students were able to identify the riskiest location (about 2/3rd of students tested gave a positive response). This further suggested that the familiarity of the risks associated with natural hazards were media related (Esteban et al., 2018). Furthermore, in a study by Phillips and Schmidlin (2014), no connection was found between lightning safety knowledge and experience with natural hazards.

There was a lack of meaningful behavioural action in the responses to the hurricane scenario. The percentage positive behavioural action responses (table 12) in the case of hurricanes was around the 50% mark, except in the case of the Estonian sample, where it was lower and where few students (4.7%) had experienced hurricanes. This suggested that there was a possible connection between experience with hurricanes and the acquisition of responsible action to take and that this would be worthy of further investigation. The lack of meaningful behavioural action was illustrated by the high number of students (about 50%) who opted to use a bicycle (compared with walking, using a boat or car), but then who further stated they would take a bicycle to the mountain top, without giving consideration that at the top there would be no shelter! While this might be a responsible action in the event of a tsunami, it was not deemed suitable in the case of a hurricane.

In general, the responses to behavioural actions across the entire student sample seemed to be inadequately thought out when undertaken by transference to an unknown situation. This suggested that the capability to transfer learning from one area of learning to another e.g. to transfer responsible behavioural action from a responsible tsunami response to a responsible earthquake response was not being achieved and this was likely due to the lack of teaching/ learning with respect to the necessary higher order thinking. This suggested that more attention to teaching associated with responsible behavioural actions in the case of natural hazards should be promoted as a key learning aspect.

Perhaps predictably, tectonic natural hazards positive responses (earthquakes and tsunamis) were much lower for earthquakes than for tsunamis, except in the case of the Japanese respondents. To account for more favourable behavioural action responses in the case of tsunamis, Esteban et al. (2018) indicated that the media had a considerable influence on student thinking. In this study, a media impact might account for the favourable behavioural actions found also for lightning situations, irrespective of whether the students were from Estonia, US-East Coast, US-West Coast, or Japan, and in spite of little mention in the respective curricula. The media impact was further supported by lightning being a natural hazard that students most commonly experienced, while tsunamis were a natural hazard that people (and hence students) tended to fear the most, with students seemingly supplementing their learning outside of the classroom.

While comprehension of NOS and NOT were viewed as important for science education (Fernandes, Rodrigues, & Ferreira, 2017; Lederman 2007; McComas, 1998), NOS/NOT responses overall were generally low, and suggest an area of concern (DiGironimo, 2011; Liou, 2015). The exception were responses in section 2 for items 2 and 3, except in Estonia. As illustrated in tables 8, results across all student groups seemed to suggest students did not adequately understand NOS for the majority of items. The lack of student NOS understanding was most pronounced for items 1 and 5, which relate to scientific knowledge being tentative yet durable (through a context of weather prediction) and the relationship between theories and laws, respectively. This was taken to be disconcerting, because it was expected that students were familiar with:

- understanding that scientific knowledge is subject to change over time (items 1 and 2);
- knowing the difference between science and pseudo-science (item 3);
- recognising there are creative, inferential and imaginative elements involved in the scientific process (item 4); and
- knowing the difference between theories and laws (item 5) are essential for building a solid foundation for learning science (Fernandes, Rodrigues, & Ferreria, 2017; Lederman, 2007; McComas, 1998).

https://doi.org/10.33225/jbse/19.18.519

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

This lack of NOS understanding was seen to be in alignment with findings in studies by Lederman (2007) and Fernandes, Rodrigues and Ferreira (2017). However, as NOS results were more meaningful in table 9, especially with respect to selecting the most appropriate choice for items 2 and 3 across all regions/countries, this strengthened the suggestion that students were not being taught adequately to comprehend NOS ideas (Lederman, 2007).

There seemed to be little indication, with respect to outcomes for NOT items in tables 8 and 9, that technological concepts were being promoted in schools. It is clear from these outcomes that the items which probe NOT understanding were unfamiliar to students and were largely beyond student comprehension.

Knowledge of NOS/NOT did not seem to impact on behavioural actions. Data were analysed by matching NOS/NOT and disposition item responses with both positive and negative responsible behavioural responses in an effort to identify potential links between NOS/NOT/dispositions and responsible behavioural actions (Oyao, Holbrook, Rannikmäe, & Pagunsan, 2015). Results from such clustering (table 13) indicated little or no connection, for all student samples, between NOS/NOT and responsible behavioural action, suggesting that any acquired NOS/NOT knowledge did not equate to promoting more responsible actions in the event of a natural hazard. Nevertheless, the true potential role of NOS/NOT comprehension in undertaking responsible behavioural action in comprehension of NOS/NOT could not be ascertained because students had little understanding of NOS and NOT, i.e. insufficient students indicated they understood aspects of NOS/NOT. It was thus not possible to indicate whether there was a connection between scientific and technological aspects associated with NOS/NOT and the taking of responsible behavioural actions.

In Estonia, outcomes, limited mention, or reference to, NOS or NOT were included in the Estonian National Curricula at the time of testing. For example,

- "Appreciate science as a process of obtaining scientific information in its historical and modern context, the role of creativity in scientific discoveries and the limitations of science" (Estonian Government, 2011, p. 1).

The NGSS standards were more explicit in indicating the inclusion of aspect of NOS and NOT (NRC, 2013). In particular, included were:

Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena

- A scientific theory is a substantiated explanation of some aspect of the natural world, based on a body of facts that have been repeatedly confirmed through observation and experiment and the science community validates each theory before it is accepted. If new evidence is discovered that the theory does not accommodate, the theory is generally modified in light of this new evidence (HS-PS4-3).
- Laws are regularities or mathematical descriptions of natural phenomena (MS-PS1-5).

Scientific Knowledge is Based on Empirical Evidence

- Science knowledge is based upon logical and conceptual connections between evidence and explanations (MS-PS4-1).

Scientific Knowledge is Open to Revision in Light of New Evidence

- Science findings are frequently revised and/or reinterpreted based on new evidence (MS-ESS2-3).

Neither NOS nor NOT feature in the Japanese curricula (MEXT, 2009). Nevertheless, while there was a lack of mention of "NOS and/or NOT" in the Japanese curriculum, the results from Japan in this study did not differ substantially when compared with US-East and West Coast and Estonia.

In general disposition responses were high, except surprisingly section 2A, item 12A in Estonia and for item 13A in all countries except Japan. Surprisingly, students from US-East Coast had a highest percentage of correct responses for items 1A, 5A and 6A. It is interesting that Japanese students had given a higher percentage correct response to item 7A relating to building a home in a safe/risky location.

Section 2B percentage positive responses were generally higher than for the corresponding section 2a percentage responses, suggesting that when students were provided a choice of context, students found it easier to select a meaningful explanation. This indicated that the learning supported students in providing a meaningful way of relating content knowledge with personal experience (Eurydice, 2012a). This especially applied to Estonian students. However, this was less apparent from student responses in the US (both East and West Coast) and Japan.

In this study, student disposition encompasses student attitudes and values/beliefs (Oyao, Holbrook, Rannikmäe, & Pagunsan, 2015) as well as a sense of responsibility (OECD, 2006). A majority of students, from all samples, responded positively to disposition items in section 2B, (items 10B, 11B, 12B, & 13B), as well as responsibly

https://doi.org/10.33225/jbse/19.18.519

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

responded in the tsunami behavioural action scenario (table 13). Positive student dispositions (based on responses to items 10 to 13) were mainly related to responsible behavioural action in the event of a tsunami or lightning strikes. This suggested that the promotion of meaningful dispositions should be further developed in order to increase the willingness to reflect on the undertaking of responsible behavioural action. For example, if students demonstrate an eagerness to learn about natural hazards and responsible behavioural action during a natural hazard, it was more likely the student will be proficient with respect to reducing risks in the event of a natural hazard. Attitudinal responses such as those for items 10 and 13 were lower in the case of Estonian students and for item 13 for students from the US-East coast (as illustrated in tables 8 and 9). Results for item 10A (in table 8), related to considering the safety of others, suggest students would focus on themselves and disregard the safety of others in the event of a natural hazard, while results for item 13, using earthquakes as a context, suggest a potential connection between earthquake frequency and attitude (willingness towards) learning to act responsibly in the event of an earthquake (table 13). This supported the suggestion of a connection between possessing positive learning attitudes and being able to undertake responsible behavioural actions. In other words, if behavioural actions were expressed associated with a positive belief, then students were more likely to recognise the behavioural action to undertake. This link was in alignment with the model put forward by Oyao, Holbrook, Rannikmäe, and Pagunsan (2015) indicating dispositions were connected with behavioural actions (such as meaningful responses to hurricanes, lightning strikes, earthquakes and tsunamis and perhaps other natural hazards).

Across all student groups in the sample there seemed to be little connection between NOS responses and putting forward positive behavioural actions (Sims and Baumann, 1983) to promote natural hazard reduction, in the case of a hurricanes, lightning, earthquakes and tsunamis. Positive NOS responses did not seem to aid the giving of positive behavioural responses (Paton et al., 2008). Only in the case of positive disposition response for tsunamis was there a potential impact on the appropriate behavioural action undertaken. In the case of hurricanes, lightning and earthquakes there seemed to be no link between the disposition responses and behavioural action. Responses to items 4A, 5A, 13A, 1B, 2B, 3B, 5B, 6B, 9B, 13B showed these had little role in determining the response pattern connected to the outcome related to behavioural action.

Conclusions

The findings show that students were better able to put forward responsible behavioural actions in the case of tsunamis, compared with the other natural hazards, and to a meaningful extent were supported by the possession of positive attitudes. In general, however, responsible behavioural actions were not in line with the transference of competences to a new situation, as per expectations. Where students were found to have a stronger awareness (based on experience, knowledge and actions) of natural hazards, irrespective of the curricula followed, or the country/region of learning, they were better able to respond to natural hazard scenarios in an appropriate manner. Not surprisingly, students were able to put forward familiar actions, as opposed to actions that were unfamiliar and which required transference of learning, but being able to indicate responsible behavioural actions seemed to be generally lacking.

Positive student dispositions (attitudes and values/beliefs), e.g. a willingness to evacuate under the threat of an impending natural hazard/disaster, suggested an increased student ability to undertake responsible behavioural actions in the event of a natural hazard. However, there was a lack of a demonstrable link between NOS/NOT and responsible behavioural actions. In general, in was found that a philosophical appreciation of what is meant by science, as expected from an understanding of NOS or even technology, as expected by an appreciation of NOT, seemed to be lacking from science learning, irrespective of the learning level. On the other hand, it seemed that more positive dispositions towards learning did tend to support the undertaking of responsible behavioural actions.

Acknowledgements

This research was supported by Target project IUT-16 of the Ministry of Education and Science of Estonia and by the EU through the European Regional Development Fund (Centre of Excellence EcolChange).

https://doi.org/10.33225/jbse/19.18.519

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Received: *February 20, 2019* Accepted: *July 10, 2019*

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https://doi.org/10.33225/jbse/19.18.519